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111-10

# Meteoroids and Meteor Storms: A Threat to Spacecraft?

April 20, 1999

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NASA

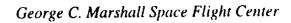
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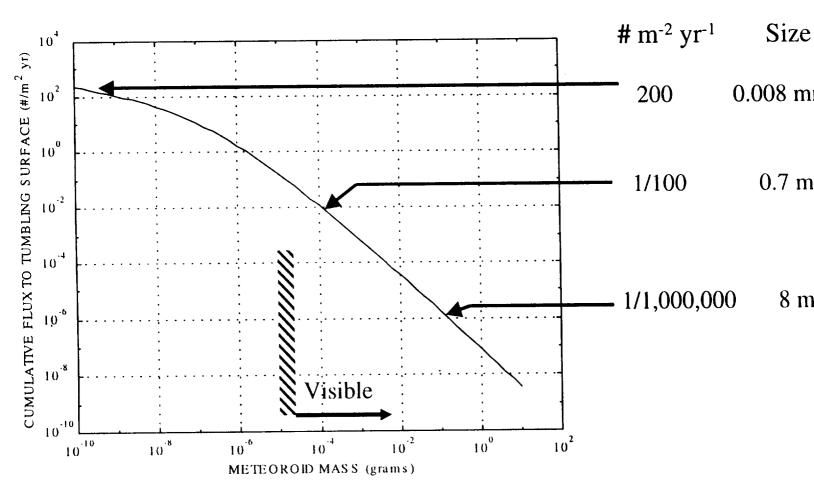
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# **Meteoroid Flux in Geosynchronous Orbit**



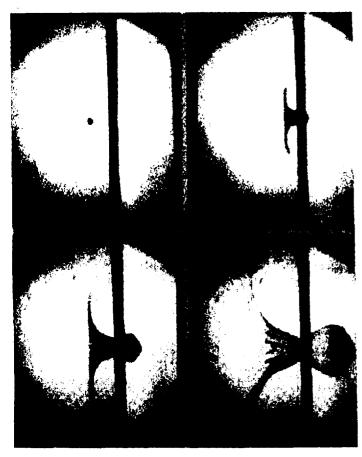


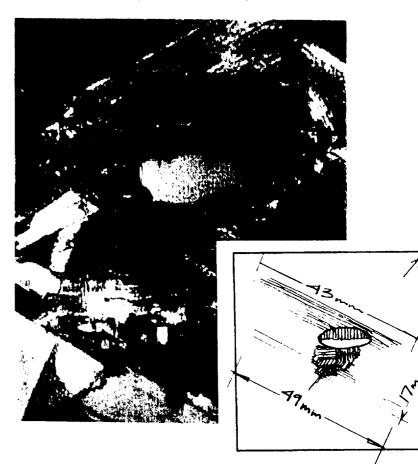


## **Hypervelocity Impact Phenomena**



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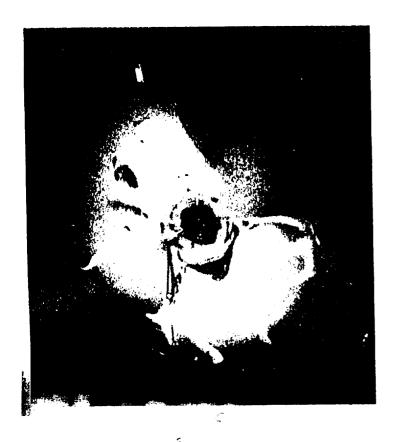
Courtesy Johnson Space Center

Left: Flash x-ray sequence. Right: Impact Damage to Graphite Epoxy Honeycomb {1/16" (5.82 mg) Al impact at 6.81 km/s on 24 layer MLI, M60J/954 Honeycomb, 0.040"/0.40"

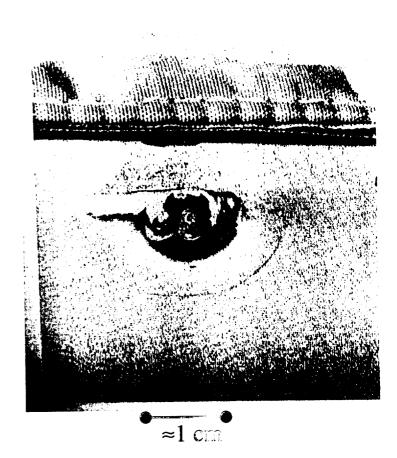
# **Impacts on LDEF Thermal Surfaces**



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at



there a blanket backed by vapor deposited silver/inconel, paint (Exp. A01 pe coated with 125 µm teflon film, silver & adhesive backed (Exp. S1005).

## **Impact Related Failure Modes**



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• Cables Short MSTI-2 (9/94) ??

Cables Cut

Pressure Vessels (explode/unzip)

• Structure Failure CERISE (7/96)

• Tethers Cut SEDS-2 (after mission)

Window Damage
 Shuttle (3 replaced / 2 missions)

Window Burnage

Light Leakage

• Electromagnetic Pulse (Meteoroids only) Olympus (8/93) ??

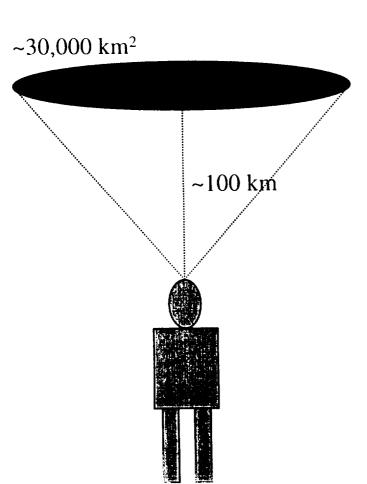
Fluid Line and Heat Pipe Leaks
 Shuttle Threat

Operator Error

## **Zenith Hourly Rate (ZHR)**



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- Meteor altitude is about 100 km.
- "Standard" Observer.
- Dark, clear sky
  - Magnitude 6.5 stars visible.
- Radiant of shower directly overhead.
- Zenith Hourly Rate is the number counted per hour.
- Background: ZHR ~ 8.
- Typical "Shower": ZHR ~ tens.
- Meteor "Storm": ZHR > 1000.
- For a 300 m<sup>2</sup> Satellite, storm conditions risk is ~ 0.00001 hr<sup>-1</sup> from visible-size meteoroids.

# **Meteor Showers**



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Meteors	<b>Dates</b>	ZHR Peak	<u>Comet</u>		
Sporadic Background	đ	8			
Quadrantids	Jan 1-6	80	unknown		
April Lyrids	Apr 19-25	15	Thatcher 1861 I		
Pi-Pullids	Apr 21-26	40	Grigg-Skjellerup		
Eta-Aquarids	Apr 24-May 20	35	Halley		
Day Beta-Taurids	Jun 23-Jul 5	20	Encke		
Perseids	Jul 15-Aug 21	75	Swift-Tuttle		
October Draconids	Oct 7-10	20	Giacobini-Zinner		
Orionids	Oct 16-30	25	Halley		
Taulids	Oct 20-Nov 30	12	Encke		
Leonids	Nov 15-20	10	Tempel-Tuttle		
s - mids	Nov 25-Dec 17	60	3200 Phaethon (asteroid		
	Dec 20-24	5	Tuttle		

# **Orbital Mechanics of Leonid Generating Comet Tempel-Tuttle**



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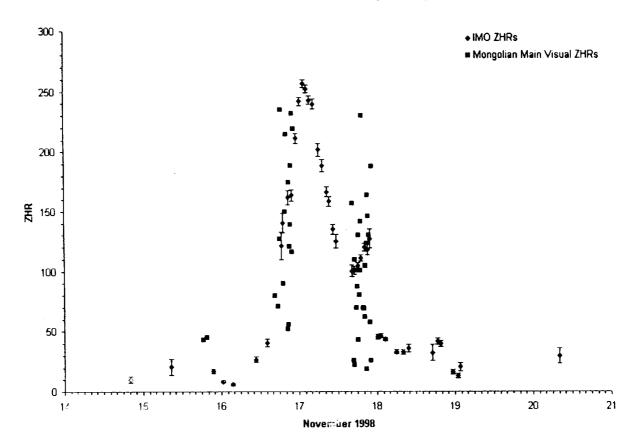
**Comet Tempel-Tuttle** Nov. 17 1997 **Position Of Earth Orbit of Jupiter Every Nov. 17 Orbit of Mars Comet Tempel-Tuttle** Nov. 17 1998 Green above ecliptic below ecliptic Courtesy of Peter Brown, University of Western Ontario

## 1998 Leonid Visual Observations



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#### Leonid 1998 ZHRs (Revised)



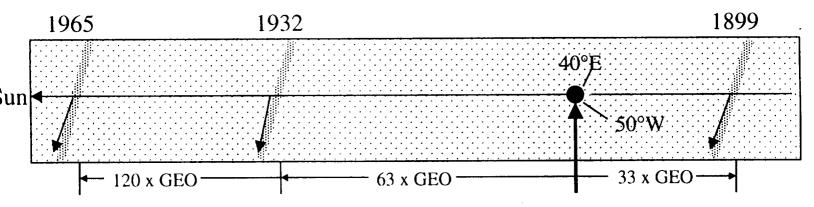
Courtesy of W. Cooke and P. Brown

## 1999 Leonid Encounter



Orbit Analysis by P. Brown, UWO; Threat Analysis by W. Cooke, CSC Inc./ MSFC

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- Encounter Velocity = 72 km/s.
- Peak Time = 02:20 UT on Nov. 18, 1999.
- Estimated Peak ZHR = 1000 to 2000.
- Width of Peak: Less than 2 hours, but with enhanced activity for several days.

#### Risk to Satellite Surfaces

Mateoroid Mass (grams)	1.E-07	1.E-06	1.E-05	1.E-04	1.E-03
Flore or finity	~ 3 E-5	~ 5 E <i>-</i> 6	~ 9 E-7	~ 1 E-7	~ 2 E-8

## **Leonid Storm Mitigation Strategies**



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- Robust Design (Minimize exposed cables and fluid lines. Assure a well grounded system.)
- Understand your system's weaknesses --- plan accordingly.

### November 18, 1999, 02:20 UT ± 3 hours:

- Orient satellite to minimize cross-sectional area and vulnerable surface exposure to the stream.
  - No problem for solar arrays since radiant is about 82° from sun.
- Notify system controllers of the enhanced likelihood of spacecraft anomalies. Keep the "Starting Team" on duty.
- Minimize operational changes, software uploads, and complex operations during this period.
- Configure to minimize high voltages on board.



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# **BACK UP SLIDES**

# **Double Wall Penetration Leonid Storm Peak**



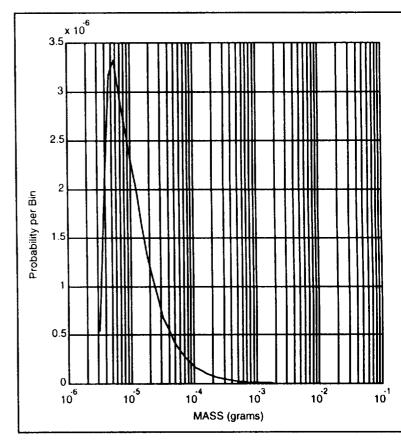
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#### **Assumptions:**

Zenith Hourly Rate = 5000
Flux = 2.8e-19 (zhr) m<sup>-1.3</sup> [m<sup>-2</sup> s<sup>-1</sup>]
One Square Meter at Random
Orientation, One Hour Exposure
0.020 Inch Al Back Wall
0.25 Inch Spacing to Bumper
No Earth Shielding

Total Probability of Penetration 2.7e-5 [m<sup>-2</sup> hr<sup>-1</sup>]

Critical Mass = 3.6e-6 g.



#### **Double Wall Penetration**

**Taylor-McBride Velocity Distribution** 

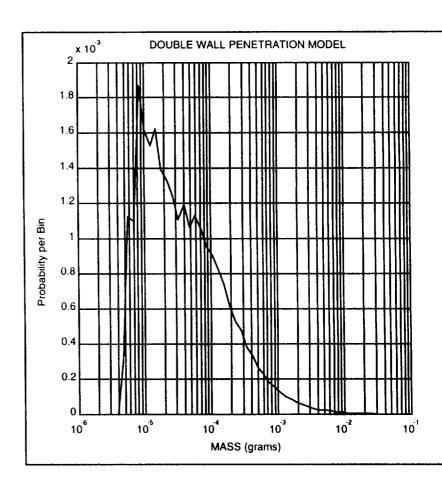


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#### **Assumptions:**

- 0.020 Inch Al Back Wall
- 0.25 Inch Spacing to Bumper
- One Square Meter, One Year Exposure
- 1000 km Altitude
- Grün / Space Station / TM 4527 Flux
- Taylor & McBride Velocity
   Distribution (3/97 Darmstadt Conf.)

Total Probability of Penetration = 0.026



## **Conclusions**



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- Robust system design is the best protection against meteoroid damage.
- Impacts by small meteoroids are common on satellite surfaces, but impacts by meteoroids large enough to damage well designed systems are very rare.
- Estimating the threat from the normal meteoroid environment is difficult. Estimates for the occasional "storm" are even more uncertain.
- Common sense precautions are in order for the 1999 Leonids, but wide-spread catastrophic damage is <u>highly unlikely</u>.
- Strong Leonid showers are also expected in 2000 and 2001, but these pose much less threat than 1999.



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Results of half inch Al projectile impacting on 0.040 inch Al plates at 6.1 km/s; 4 in. spacing; 0.125 in. back plate.